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Expanding Opportunities Through On-Demand Learning

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In this chapter, we discuss the prospect of on-demand learning—education, training, problem solving, decision aiding, and so forth—that is available anytime, anywhere to anyone who seeks it. This differs from the related notion of "ubiquitous computing," which involves flooding classrooms with technology and is an important area of inquiry itself (e.g., Swan, van't Hooft, Kratcoski, & Schenker, 2007). Studies of ubiquitous computing typically focus on in-classroom learning. We, too, are concerned with classrooms but more generally with the impact on schools and classroom learning when on-demand learning pervades our lives in every other venue.

The appeal of making human knowledge universally and readily available through on-demand learning seems hard to deny. It should benefit individuals and teams of individuals in schools, businesses, and organizations—in every economic sector that relies on human competencies. It will, however, affect the status quo in all these sectors. Here, we discuss the opportunities offered by on-demand learning and provide some speculation on its impact and the challenges it poses for education.

We do not distinguish between education (such as we find in schools) and training (such as we find in business and government), although we concentrate on the former. We assume that both education and training lie on a common dimension, which we refer to as learning (Tobias & Fletcher, 2000). On demand, anytime, anywhere learning is as likely to affect 21st-century educators, instructors, and researchers on both ends of this dimension as it is the institutions they serve.

About On-Demand Learning

On-demand learning involves the delivery of materials that can be used

- in training to prepare people for specific tasks and jobs and in education to prepare people for careers and lives;
- as performance aids for solving problems and decision making at all levels of responsibility;
- in formal venues, such as K–16 schools and industrial training, and in informal venues, such as homes, museums, and workplaces; and
- by students working individually or collaboratively, any or all of whom may be physically present in classrooms or globally dispersed in both time and space.

On-demand learning can be delivered by computers, mobile phones, and/or various handheld personal digital assistants (PDAs). It is interactive and often collaborative, employing techniques of instant messaging, computer-based instruction, virtual reality, the World Wide Web, computer simulations, and games.

These capabilities now exist. While they can all support classroom learning, they are also capable of transcending it. It has been posited that using the standard classroom means for instruction have reached an asymptote, while more interactive, technology-based means are likely to continue growing in quantity, capability, and popularity (e.g., Branson, 1998; Bush, 2007). This possibility places a premium on technologies that adapt in real time to the needs, background, and goals of individual learners.

In education, increasing the accessibility of learning will enhance communication and cooperation between students, homes, communities, and K–16 schools. It will help harmonize the learning processes and procedures of schools with our rapidly evolving workplaces. Notably, it will enable schools to reach students with special needs more readily, especially those who are homebound. Increasing the accessibility of learning also allows those who are gainfully employed and unable to spend extended times on campus to receive the instruction required for new jobs and careers. It enables schools to offer many elective and advanced placement courses that they could not otherwise make available. Finally, it facilitates collaborative and situated efforts by students working together to investigate phenomena and solve problems.

Possibilities and Predictions

One way to provide on-demand learning is to fill rooms with multilingual polymaths who are available anytime to answer questions from learners calling in from anywhere. Such an approach is both economically and functionally impractical—although occasional "reach-back" access to subject matter experts is not out of the question. Realistically, however, we must rely on technology to supply the heavy lifting needed for on-demand learning. What technological capabilities, then, are emerging that we might apply? What might we envision for our 21st-century expanded opportunities for learning?

Few undertakings are as precarious as predicting the future. Samuel Johnson may have been right in saying that the main value of predicting the future is to provide amusement for those who live in it. Yet efforts using a futurist perspective to plan for and implement educational change have demonstrated the usefulness of such predictions.

For instance, Tobias (1977, 1980) reported on projects that examined curricula in different vocational education fields from the perspective of the knowledge, skills, and attitudes students would need in the 21st century. The projects examined trends in many areas and then projected them from the 20th to the 21st century. Many of these projections turned out to be accurate. They prompted New York state to modify the statewide business education curriculum, and eventually all of its vocational education curricula. These changes had a significant and favorable impact on the lives and careers of students throughout New York state.

We hope that projections for on-demand learning made in this chapter will be equally accurate and effective. It is also said that the future is already here, but unrecognized and unevenly distributed. Perhaps, then, a brief examination of overlooked and unevenly distributed trends that might coalesce to expand opportunities for learning is in order. Items that apply to such a prediction include the following.

Moore's Law. In 1965, Gordon Moore, a cofounder of Intel, noted that engineers were doubling the number of electronic devices (basically transistors) on chips every year (Brenner, 1977). In 1975, Moore revised his prediction to say that the doubling would occur every 2 years. If we split the difference and predict that it will occur every 18 months, our expectations fit reality quite closely. The implications of Moore's Law with regard to size and cost of computer capabilities have, for better or worse, become obvious. A recent survey of the Institute for Electrical and Electronics Engineers (IEEE) Fellows found that they expect Moore's Law to continue holding for at least 10 years. About 35% of them expect it to continue beyond that, from 11 to 20 years (Gorbis & Pescovitz, 2006).

Computer Communications and Networking. The most dramatic and globally pervasive manifestations of computing in our daily lives may be the Internet and the World Wide Web. Web use grew about 225% between 2000 and 2007, with about 1.175 million users worldwide. About 69% of the North American population now has access to the Web. Globally, over 3 billion Web searches are performed each month (Internet World Stats, 2007). Blogs, chat rooms, wikis, instant messaging, the Wikipedia, and similar capabilities have made vast amounts of human information—and misinformation—globally accessible. Today, these capabilities are unevenly distributed, but at least they are commonly recognized. Work has begun to integrate these capabilities with a focus on learning (e.g., Sitzmann, Kraiger, Stewart, & Wisher, 2006), but more remains to be done.

Bush (2007) noted an interesting disparity between use of on-demand technologies for leisure and those employed for learning. Mobile technologies, such as the iPod, a seemingly infinite variety of MP3 players, personal organizers, mobile telephones and Web surfing equipment, among a host of other devices, are used extensively and on demand for leisure. Yet, it is often noted that an 18th-century visitor to most 21st-century classrooms would encounter virtually no on-demand learning technologies. Such a visitor would feel very much at home, finding little that was unfamiliar. We expect that the wide use of on-demand technologies in leisure pursuits combined with rapid development of related technology will gradually enter classrooms. As previously noted (Tobias, 1985), the introduction of computers in classrooms was stimulated by their ubiquity in business and industry. We expect on-demand learning technologies to follow a similar course.

The Semantic Web. The Semantic Web (Berners-Lee, Hendler, & Lassila, 2001), which is being developed under the auspices of the World Wide Web Consortium, may become a significant factor in the development of on-demand learning (Devedzic, 2006; Dodds & Fletcher, 2004; Fletcher, Tobias, & Wisher, 2007). It should improve cooperation between computers and human beings by imbuing Web information with meaning using ontological connections. These connections are expected to identify semantic linkages between disparate bodies of knowledge regardless of how different they may first appear to be (e.g., Chandrasekaran, Josephson, & Benjamins, 1999).

If successful, the Semantic Web will integrate the real-world knowledge and skills each learner has acquired through education, training, performance aiding, and life experience. It will provide a foundation for building far more comprehensive and substantive models of both subject matter domains and learners' levels of knowledge than we have now. If, for instance, there are semantic linkages between a specific third grader's knowledge of geography and economic history taught in universities, the Semantic Web will find them.

Combining the emerging Semantic Web capabilities with those already available for on-demand learning may provide the basis for a next-generation learning meta-architecture that might be viewed as the deep structure for instructional interactions and conversations analogous to Chomsky's notions (e.g., 1965) of deep structure for grammar. They may extend the foundations of instructional design to include principles derived from linguistics and narrative theory.

Intelligent Tutoring Capabilities. Since the 1960s, most common computer-based instructional programs have had the capability to adjust (1) individual students' rate of progress; (2) sequence of instructional content to match each student's needs; (3) content itself—providing different students with different content depending on what they have mastered; and (4) the difficultly level most appropriate for each learner in accord with ideas as ancient and durable as Yerkes and Dodson's (1908) inverted "U" and Vygotsky's (1978) zone of proximal development. These capabilities have been available and used in computer-based instruction almost from its inception in the 1960s (e.g., Atkinson & Fletcher, 1972; Fletcher, 1992; Suppes & Morningstar, 1972), even though they are not applied as widely as they could and should be. Those who currently promote learning systems, touting these features as indicators of newly developed "intelligent" capabilities, may be missing some history.

Intelligent Tutoring Systems add at least two capabilities to those previously available from computer-assisted instruction.

- First, the ability to generate instructional material and interactions on demand rather than require developers to foresee and prestore all such materials and all possible interactions.
- Second, and related to the above, the ability envisioned by Carbonell as early as 1970 to allow either the computer or the student to ask open-ended questions, that is, to engage in "mixed-initiative" dialogue as needed or desired.

These two capabilities suggest that on-demand learning could take place as guided conversations rather than didactic presentations, perhaps supplemented by formal lessons, explicit assessments, and assignments. Instruction based on individualized, mixed-initiative dialogues could substantially alter current practices in education and training as well as the focus, concerns, and approaches of instructional design.

Natural Language Processing. The steadily growing capabilities of computer technology to understand human language will significantly enhance the capabilities of mixed-initiative dialogue. Computer-based tutoring systems developed from the 1970s (e.g., Brown, Burton, & DeKleer, 1982) until today (e.g., Graesser, Gernsbacher, & Goldman, 2003) have used computer understanding of natural language, both textual and spoken, in learning systems. These systems have demonstrated the feasibility and utility of natural language interactions in technology-based instruction. Given the economic windfall that could result from reliable understanding of natural language by computers, it seems likely that these capabilities will continue to receive significant investment and continued growth.

Computer Graphics, Video, and Animation. The validity of the Multimedia Principle, which states that people learn more from words and pictures presented together than from words alone (Mayer, 2001), seems well established by research (cf. Fletcher & Tobias, 2005). Multimedia capabilities applicable in on-demand learning are being extended well beyond books and other text media by advances in computer graphics, animation, and video.

Handheld, Wireless Computing. The world of personal computing is riding the crest of Moore's Law and expanding rapidly into handheld devices. It may well continue until these devices are worn as clothing. Over 130 million handheld, wireless devices were sold in 2006, the number of mobile phone users now exceeds 3 billion, and podcasting is growing by 101% a year with over 56 million podcast devices expected to be in use by 2010 (Baugh, 2007).

Electronic Performance Aids. The cost-effective value of portable, electronic performance aids in equipment maintenance and problem solving has been reviewed by Fletcher and Johnston (2002). The trend to develop and employ portable, handheld, or even wearable devices used to solve problems or aid decision making by accessing precisely targeted information in large data bases seems likely to continue, albeit slowly. The first of these systems, which was wearable, voice interactive, and graphics capable was the Voice Interactive Maintenance Aiding Device (VIMAD) produced by the Defense Advanced Research Projects Agency in the late 1970s (Dray, Ogden, & Vestwig, 1981). Techniques being developed for these performance, problem-solving, and decision aids will add to the technical capabilities now used to support collaborative, "situated" problem solving in education.

Object-Oriented Technology. The development of object-oriented software techniques and capabilities along with the development of specifications and standards to make them accessible, portable, platform independent, reusable and durable despite changes in underlying system software in such projects as the Advanced Distributed Learning initiative have been described elsewhere (cf. Fletcher et al., 2007). These developments have done much to make on-demand learning practical. Materials stored as objects and packaged in metadata that describes what is in the package can now be targeted by learners seeking a particular instructional resource or knowledge object, with reasonable assurance that it can be located, accessed, and run on any computing platforms learners have available.

Personal Learning Associates

The development of game-playing telephones, eager acceptance of iPods, ubiquity of instant messaging, growing PDA dependencies, and similar trends, all anticipate the likely and perhaps imminent appearance of what might be called Personal Learning Associates (PLAs). Fletcher (2006) has noted that we might soon expect to find our roomful of polymaths to be electronically compressed, carried in every person's pocket, and used to access the whole of human knowledge on the Web. PLAs will filter this information for relevance, tailoring it to learners' prior knowledge, abilities, interests, objectives, and experiences.

Functional characteristics of PLAs would include the following:

Wireless Operation. PLAs might well be equipped to communicate with other PLAs, keyboards, larger computers, and, of course, the global information infrastructure. Further, they would be designed and expected to operate in wireless mode.

Access to the Global Information Infrastructure. The Internet and World Wide Web are still evolving. Global information infrastructure seems as useful as any other term for whatever form these capabilities take. In any case, nearly everything that is available (given firewalls, parental guidance capabilities, etc.) on the information infrastructure should be identifiable, locatable, and accessible by each person's PLA.

Some of this access may take place through the exchange of digital objects that are packaged and identified in accord with specifications developed by the Advanced Distributed Learning initiative (Fletcher et al., 2007). In that project, the Shared Content Objects Reference Model (SCORM) ensures that instructional objects follow common conventions that enable them to be retrieved and applied by others. In addition, infrastructure capabilities such as the Content Objects Registry/Repository Discovery and Resolution Architecture (CORDRA) help to identify, locate, and access objects with precision (Fletcher et al., 2007). CORDRA goes beyond the "text crawling" procedures of current search engines and, thanks to metadata packaging and ontologies, allows substantially more precise location of the digital objects being sought. Its precision can be expected to continue improving significantly. CORDRA is not a search engine, but is better described as infrastructure.

Collaboration and Communication. Related to their capabilities for wireless operation and information infrastructure access, PLAs will help users learn, solve problems, and make decisions collaboratively, despite their physical and temporal separation. Additionally, there seems to be every reason to expect PLAs to incorporate software tools (e.g., Soller & Lesgold, 2003) that both identify communities of interest and enhance their capabilities for collaboration.

Natural Language Interaction. Mixed-initiative, natural language interaction, spoken or textual, should be the basic mode of communication between learners and PLAs. Keyboard text input may remain necessary in the short term to avoid technical difficulties as well as the variations and vagaries of speech. Eventually, however, computer capabilities may outstrip human capabilities for understanding all dialects of natural languages.

User Modeling. Because each PLA will be a personal item, it will be able to use routine interactions to develop a model of the learner's knowledge abilities, interests, and values. This model can become the foundation for mixed-initiative interactions and help identify sequences, knowledge objects, and resources that are tailored to each learner's needs for information and instruction.

Subject Matter Modeling. The PLA may become a subject matter expert on-demand by collecting and organizing information from the global information infrastructure. PLAs may use machine learning techniques to assess and abstract principles from the information it gathers. It may also identify gaps, misconceptions, and contradictions. Applications as early as BIP in computer programming (Barr, Beard, & Atkinson, 1975), EXCHECK in mathematical logic (Suppes, 1981), and SOPHIE in electronic trouble shooting (Brown, Burton, and DeKleer, 1982) demonstrated that computer capabilities to model subject matter expertise in at least some domains are within our technical grasp.

Pedagogical Capabilities. PLAs require computer technology. Research collected by many studies has shown that computers can be used to teach (e.g., Fletcher, 2004; Kulik, 1994). One statistical finding that has emerged from reviews of this research is the Rule of Thirds, which holds that use of interactive computing reduces the cost of instruction by about one third, and, additionally, either reduces time of instruction (holding achievement constant) by about one third or increases the amount learned (holding time constant) by about one third (Dodds & Fletcher, 2004). The Rule of Thirds is strictly a statistical summarization. It does not claim the causal linkages between technology and learning decried by Clark's (1983) often-cited argument against the assignment of cause to media delivering instruction. However, PLAs will provide essential capabilities for creating environments that engender learning and problem solving by individuals and groups of individuals.

Additionally, Bush (2007) cites data reported by Bradshaw and Crutcher (2006) indicating that 77% of the cost of the typical college textbook is absorbed by the production and distribution of the product. Nearly all of these costs could be eliminated by electronic distribution. Similar cost considerations doubtless apply to education at all levels. Once issues of remuneration for use of proprietary materials are worked out, more of these materials can be transmitted to PLAs and similar electronic equipment on-demand, anywhere and anytime.

Benefits and Challenges

Some Benefits

At least four general benefits, and a number of challenges arise from on-demand, anytime, anywhere teaching-learning environments:

More Individualization. The use of digital learning objects to provide on-demand learning environments enables affordable, real-time, responsive interactivity (Fletcher, 2001; Gibbons, Nelson, & Richards, 2000). This adaptive interactivity seems especially important in education where objectives may be negotiable as teachers and students work together to identify and develop each individual's abilities, interests, and values.

Continuous Assessment. Assessment in instructional conversations can become continuous and less intrusive as capabilities for generating models of individual learners from their instructional interactions evolve. Such assessment may occur by monitoring the learner's technical vocabulary, use of technical information, level of abstraction, clustering (chunking) of concepts, hypothesis formation, solution paths, error rates, and the like. These capabilities have yet to be fully explored and verified, but enough research has been completed to suggest their promise for the adaptive assessment of knowledge and abilities needed to tailor instruction to learners' needs (Fletcher, 2002). Explicit testing may still be needed to assess learner progress efficiently. A blend of continuous assessment capabilities with explicit probes such as tests and questionnaires will allow educators to better integrate evaluation with instruction as Baker (2003), among others, has identified as an imperative.

More Learning. Increasing the accessibility of learning resources is a worthy goal. Results from research on tutoring, individualization of instruction, and computer-assisted instruction all support the common-sense notion that learning can be substantially enhanced by increased accessibility (e.g., Fletcher, 2004).

Open Environments. On-demand learning resources, unlike other educational innovations, do not presuppose any organization of the environment in which they may be accessed and used. In addition to being available anywhere and anytime to individuals working alone or in groups, they may also be accessed in traditional classrooms where a teacher directs the learning of all students simultaneously or in classrooms where instruction is largely individualized.

Some Challenges

Individualization. Thorndike (1906) stated in his *Principles of Teaching* that "The practical consequence . . . of individual differences is that every general law of teaching has to be applied with consideration of the particular person . . . the responses of children to any stimulus will not be invariable like the responses of atoms of hydrogen or of filings of iron, but will vary with their individual capacities, interests, and previous experience" (p. 83). A continuing theme throughout Thorndike's research was to find ways to deal with the immense variety of individual differences found in classrooms. Bloom (1984) has described the gap between individual tutoring and one-on-many classroom instruction as the 2-Sigma Challenge—that is, how can we make one-on-many instruction as effective as one-on-one tutoring and thereby fill the 2-Sigma gap? Scriven (1975) described individualization as an educational imperative and an economic impossibility. It seems likely, as often suggested by Fletcher (1992, 2001, 2004), that technology offers an affordable means for meeting Bloom's 2-Sigma Challenge.

Tobias (e.g., 1982, 1985, 1989, 2005) has long argued the need to adjust instruction to the prior knowledge of the learner, which is a capability found in computer-assisted instruction programs from the outset. The capability to adjust pace, content, and sequence of instruction to the needs of learners exists. This capability has been in place since the earliest applications of computer technology in instruction, even though it has not been applied as widely as it could be.

The challenge is to develop a student model from a learner's routine interactions with technology that can tailor and individualize both learning and problem solving. Research is needed to answer questions like the following. Should we rely solely on explicit testing and assessment, or should we aim for some optimal blend of explicit testing and careful monitoring of students' progress? What measures are particularly useful in individualizing instruction and how should we best use them? How can we best use data from simulations and games to develop models for users? Should we rely on overlay models that compare learner responses to those of a subject matter expert, or should we deal directly with learner misconceptions?

Ultimately, providing one-on-one tutoring with computers and PLAs will produce challenges, opportunities, and capabilities that we now perceive only dimly. Wireless telegraphs, horseless carriages, and a host of other technological innovations have led us into territory unenvisioned in the original, precipitating metaphor. We should anticipate and prepare for a similar effect with the advent of PLAs.

Adapting to Change. The importance of anytime, anywhere learning is emphasized by the rapid pace of change in society. The need to deal with change is underlined by Funk and McBride's (2000) projections showing that existing procedures in most work settings change both frequently and dramatically and that occupations, even whole professions, will develop and disappear in the future as technology continues to assume some of the responsibilities formerly discharged by people. Of even greater concern, they suggest, is the expectation that "the change is likely to be chaotic, and will not appear to follow a 'grand plan'" (p. 550). Similarly, Quinones and Ehrenstein (1997) suggest that "trends point to an uncertain future in which organizations will have to adapt continuously to . . . ever changing and increasingly volatile (situations) . . . as a consequence of the implementation of new technological processes or the obsolescence of existing processes" (p. 11).

The need for people and organizations to adapt rapidly to change does not arise solely from technological advances. More generally, Tan (2007) has pointed out that "The uncertainty of a flu pandemic, unprecedented scale of environmental disasters, terrorism, and complex political and social-economic problems all point to the need for education to prepare our students for a rapidly changing and sophisticated world. The ability to learn when plunged into an unfamiliar situation and to adapt positively to rapidly changing demands is a reality for every worker today" (p. 227) and also for every student.

Helping individuals deal with change, then, becomes an important goal for anyone concerned with learning. One can anticipate people, in school and at work sites, being continually baffled by changes that were not foreseen and for which they have not been adequately prepared. The projections summarized earlier suggest that such circumstances will arise with increasing frequency as the pace of technology development and the volatility of world events continue. Puzzled individuals are likely to welcome assistance from instructional materials, performance aids, and other nonhuman resources available for solving unanticipated problems. These considerations further emphasize the value of on-demand learning available anytime and anywhere.

Needed Research

The advent of on-demand learning raises challenging questions that need to be addressed by research. Some of these questions have been identified earlier in this chapter, others are briefly reviewed below. Interested readers will raise new questions, and still others will arise in the future.

Conversation-Based Learning. How should we best use mixed-initiative dialogue to provide instruction and performance/decision aiding to learners? When should the learner or the technology take the initiative? Should the dialogue begin with explicit instructional interactions or with open-ended questions to provide content for the subsequent conversations? What are the best indicators in the instructional conversations for developing the student model? When should more formal approaches such as drill and practice, lessons and lesson modules, or even simulations and games be introduced? How should data dealing with students before the beginning of the conversations be used in developing the student model? Tobias (2005) presented data indicating that the most useful information for instructional adaptations may come from immediately preceding interactions with the learner, rather than information (e.g., test results) collected earlier. Are these results equally applicable to instructional conversations?

Teacher Preparation. What will be the roles and responsibilities of teachers once on-demand instructional resources become routinely accessed and used by learners? How should we help them use on-demand learning resources effectively and appropriately? The advent of on-demand learning can produce situations in which students become more expert than their teachers. How should teachers help learners find, assess, and apply information when the expertise of their students in an area may exceed their own? How should we prepare teachers to deal with collaboration and the sharing of information and misinformation among students?

Evaluation and Credentialing. How should learners who use on-demand resources be evaluated and by whom? How will such learning be harmonized with existing curricular objectives? How will it be accredited and or contribute to credentialing requirements?

Budgeting. Instructor contact hours are commonly used to establish budgets and staffing for education and training. These procedures work fairly well for standard classroom practice. But what will happen in on-demand learning when the number of students a teacher can serve increases dramatically and may well be unknown? Should we reduce budgets proportionally? Increase them?

Roles and Responsibilities of Schools. Discussions about the role of teachers in technology-based learning abound. These discussions should also consider the roles and responsibilities of the institutions that teachers serve. What are the responsibilities of schools when instructional resources are available anytime, anywhere, and on-demand? How should the activities and capabilities of formal education be "blended" with on-demand resources?

Privacy. If PLAs are capable of modeling student progress, interests, and abilities, who should have access to this information? To what extent should teachers and schools use this information in managing the learning progress of their students? What policies and protections are needed?

Equity. Learners from poor and minority backgrounds have less access to technology than their more fortunate peers. There is a lack of equity even in the content available (Lazarus & Mora, 2000). This "digital divide" allows more access by affluent learners to on-demand resources than their less affluent peers, and wealthier learners are more likely to have easier access to PLAs than others. An equitable, democratic society should develop measures to mitigate this digital divide.

Intellectual property. How should educators and learners themselves be compensated—financially, in released time, or via other means—if they develop materials for use in on-demand learning? What protections should be available and provided for developers of these products?

Many potential research issues remain dimly foreseen and understood at present. They will become obvious and significant with time and further development of on-demand learning. We hope that educators, educational administrators, and education researchers will begin to address these issues and be prepared to resolve them as on-demand, anytime, anywhere education, training, and performance aiding become as ubiquitous as e-mail, instant messaging, blogs, and cell phones are today.

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